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# Determination of lime tree (*Tilia begonifolia* Stev.) stems form based on quantitative parameters (Study area: Shafaroud forests of Guilan province, Iran)

*Mohammad Rasoul Nazari Sendi*[1] ✉, *Iraj Hassanzad Navroodi*[1], *Hassan Poorbabaei*[1], *Mohammad Sheikhkanlu Milan*[1], *Behzad Bakhshandeh*[2]

[1] University of Guilan, Faculty of Natural Resources, Forestry Department, No 62 Daneshgah St, Gaz Sq, P.O.Box 1144, Sowmeh Sara, Guilan, Iran, phone: +989116177552, e-mail: m.nazarisandi@gmail.com

[2] Lorestan Universitiy, Khoram Abad, Lorestan, Iran

## Abstract

The lime tree is one of the rare and valuable species that found in the Hyrcanian moist forests with economic as well as ecological value. Identification of the quantitative and qualitative features of this species is important. In order to investigate the stem form of this species in the Shafaroud forests of Guilan Province, 141 lime trees in 39 plots were analyzed during the four stages of small pole, pole, saw-timber, and maturity. In each plot, stem-diameter at different heights was measured by using the Spiegel Relaskop. Measurements and analyses included diameter at breast height (d.b.h.) and total height. Same parameters was calculated: stem form factor based on diameter, stem form factor based on volume, form quotient, slenderness factor, ratio of stem height to total height, ratio of stem volume to total volume, correlation, and coefficient of determination to describe stem form factor. The results showed that the average stem form factor based on diameter was 0.554. The average stem form factor based on volume was 0.576, average form quotient was 2.32 and slenderness factor was 35.04%. The average ratio of stem height to total height was 82.45. In addition the results indicated a strong relationship between diameter at breast height and trunk coefficient. The ratio of stem volume to total volume revealed that 64.44 of lime volume is located in the bottom half of the trunk. The value of the parameters described here is towards a better description of stand characteristics. Obtained results indicating stability for natural lime tree in Iran.

## Key words

stem form factor, stem form quotient, slenderness factor, coefficient of determination

## Introduction

Hyrcanian forests of northern Iran belongs to the broad-leaved deciduous forests (Marvimohajer 2005). These forests home to more than 130 species of trees and shrubs (Sabeti 1994) are located in the Alborz Mountains and along the southern coast of the Caspian Sea (Khosroshahi and Ghavami 2005). Understanding and awareness of the characteristics of these species can contribute to program planning of forests and forestry



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in the future. The genus *Tilia* is one of the valuable plant genera with a scattered geographical and altitudinal distribution throughout the Hyrcanian forest. The lime species are expanding mostly in temperate regions of the northern Hemisphere, in Asia (which has the greatest diversity of species), Europe and eastern North America (Plotnik 2000). The distribution of the lime tree in Asia includes the Caucasus, the Talesh Mountains, and the Hyrcanian forests with a limited spread in north Anatolian (Browicz 1982). In terms of ecology, the lime is a mesophyll tree. Usually single-base, found in the northern forests, and its longevity reaches more than 500 years. The stem length form of the lime tree, like the forms of other trees, does not typically have a regular geometric shape. Shoot parts are like cones, the middle one resembles a paraboloid and the basal a neloide (Avery and Burkhart 2002). To compare tree stems from one species in different habitats, stem and trunk diameter were measured at different heights and a proportion or percentage of the base diameter was calculated (Zobeiry 2005).

Some of the most important factors in stem variations of the tree trunk are species, tree position in the forest stand, stand density, ground state, and diameter of the tree. The three factors of silviculture genetics, human intervention (tending operations), and habitat conditions (ecological) sets tree shapes with varying degrees (Marvimohajer 1976). Metzger's (1893) theory showed that the overall shape of tree resembles the parabloid; however, due to the difference between stem tree parts and scenarios, it is better to divide the trunk into several parts for shape evaluation. The shape of each portion compared with geometric volume and from the equation is used to calculate the precise amount of trunk volume. Since accurate measurements of stem geometry are not obtainable for individual trees, scientists offered mathematical and correction factors. Using these coefficients and relationships, even if no volume table exists, the actual amount of tree volume can be estimated with a certain approximation (Amini et al. 2007). The slenderness factor is calculated from the diameter at breast height to the tree volume ratio and is the indicator of environmental effects on the trees. In general, these factors are suitable for the early growth of trees and for fast-growing species; however, they are reduced with increasing age and size of tree (Akhavan and Namiranian 2007). The determination of the stem diameter at different heights is used in determining the amount of wood in different sizes and to determine the quality of standing trees. Cylindrical stems of trees with lower wood loss resulting in better quality. Trees with a more cylindrical stem have less wood decline and better quality (Pourbik 1976). To show the longitudinal section of stem, characteristics are used that in which changes in stem diameter at different heights are measured relative to a benchmark. Including these characteristics: form quotient, stature stretched factor and form factor (Namiranian 2006). Mirabdolahi et al. (2011), investigated the form factor of beech trees. Their results showed that form quotient and form factor in the small pole stage (diameter at breast height of 10 to 30 cm) with the rest of stages was significant at 5% level difference. The purpose of this study is to investigate the characteristics of the lime trees of Shafaroud forest in Guilan province, including diameter at breast height, stem form factor based on diameter and volume, form quotient, stature stretched factor, ratio of stem height to total height, ratio of stem volume to total volume, correlation, and coefficient of determination.

## Material and methods

### The study area

This study is situated in the 7, 16 and 17 districts of the Shafaroud watershed. The study area is characterized as follows: elevation from sea level is 250–1650 m; average annual temperature is 15.4°C; minimum and maximum slopes are 10–80%; canopy cover is 70–80%; mean pre-

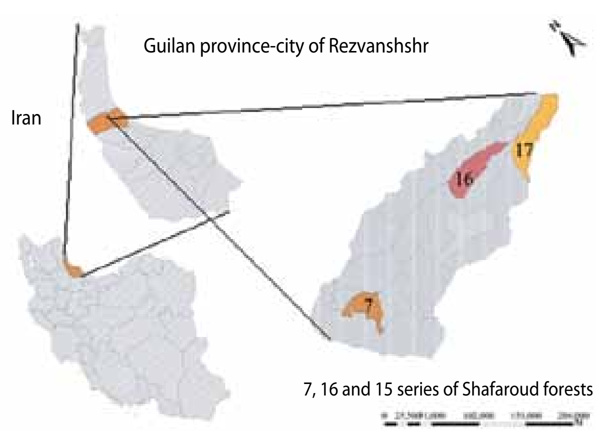


**Figure 1.** Location of study area

cipitation is 1400 mm; and the largest rainfalls occur in spring and autumn. Due to maximum temperatures, relative air humidity is low, and maximum relative air humidity occurs in the winter season. Important tree species in the study area include beech (*Fagus orientalis* Lipsky), hornbeam (*Carpinus betulus* var. *schuschaensis*), oak (*Quercus castaneifolia*), maple (*Acer cappadocicum*), lime tree (*Tilia begonifolia* Stev.), ash (*Fraxinus coriariaefolia*) and alder (*Alnus subcordata*). The climate of the study area is cool and humid (Sabeti 1995) and study area indicated in figure 1.

### Methods

For the study, 141 individuals of lime-tree that have not been impacted by human disturbances and hurt from the fire were selected. Trees were selected in such a way that four stages of small pole, pole, saw-timber, and mature trees could be included. In the study area, 39 plots, each with an area of 0.1 ha and a 200 × 200 network, were selected. In the plots, the geographical coordinates of trees with centimeter accuracy from the plot center and Azimuth were recorded. Tree trunk diameters at different heights were measured using a Spiegel Relaskop, diameter at breast height was measured by Caliper, and diameter at heights of 0.1, 0.3, 0.5, 0.7, 0.9, trunk height, and total height were measured by Spiegel Relaskop.

To calculate the form quotient per one meter of tree trunk length equation (1) was used (Zobeiri 2005).

$$df = \frac{d_{1.30} - d_{0.5}}{\frac{h}{2} - 1.30} \tag{1}$$

where:
$d_{1.30}$ – diameter at breast height based on cm,
$d_{0.5}$ – diameter at semi-tree based on cm,
$h$ – tree height based on m.

In order to calculate the tree form factor based on volume, we used from ratio actual volume to cylindrical volume (Zobeiri 2005). Diameter and height of the cylindrical base were considered equal to diameter at breast height and total height of tree.

$$f = \frac{v}{d_{1.30}^2 \times \frac{\pi}{4} \times h} \tag{2}$$

where:
$v$ – tree volume that calculated with volume table,
$d_{1.30}$ – diameter at breast height,
$f$ – tree form factor.

Form factor based on diameter calculated with the HOHENADL method (Zobeiri 2005).

$$f_{0.1} = 0.2 + \frac{d_{0.3}^2}{d_{0.1}^2} + \frac{d_{0.5}^2}{d_{0.1}^2} + \frac{d_{0.7}^2}{d_{0.1}^2} + \frac{d_{0.9}^2}{d_{0.1}^2} \tag{3}$$

where:
$d_{0.1}$, $d_{0.3}$, $d_{0.5}$, $d_{0.7}$, $d_{0.9}$ – trunk diameter in the 0.1, 0.3, 0.5, 0.7 and 0.9 heights of trees.

To calculate the slenderness factor, the ratio of total height based on m to diameter at breast height based on cm was used (Namiranian 2004).

$$Hd = \frac{h}{d_{1.30}} \times 100 \tag{4}$$

where:
$h$ – trunk length based on meter,
$h_t$ – tree total height based on meter.

In order to investigate the ratio of stem height to total height $H_R$, equation (5) was used.

Also Stem volume to total volume ratio was calculated using the relative height (Loetsch et al. 1973) and data was analyzed using SPSS16 and Excel 2010 software.

$$H_R = \frac{h}{h_t} \times 100 \tag{5}$$

## Results

Average, maximum, and minimum values and standard error rate were calculated for each of the variables of stem form factor based on diameter, stem form factor based on volume, form quotient, slenderness factor, and ratio of stem height to total height and are given in table 1.

Slenderness factor percentage was calculated for all trees. The results showed that mean slenderness factor was equal to 35.04, minimum and maximum stature stretched factor are between 9.4 and 93.75 (fig. 2 and tab. 1).

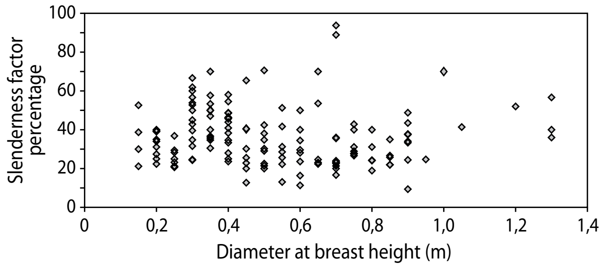


**Figure 2.** Percentage of slenderness factor of sample trees

**Table 1.** Statistical parameter indicators of sample trees

| Variables | Max | Min | Average | Standard deviation |
|---|---|---|---|---|
| Stem form factor based on volume (*f*) | 0.731 | 0.405 | 0.576 | 0.14± |
| Stem form factor based on diameter ($f_{0/1}$) | 0.732 | 0.325 | 0.554 | 0.09 ± |
| Form quotient (*df*) | 3.89 | 0.530 | 2.32 | 0.65 ± |
| Slenderness factor (*Hd*)% | 93.75 | 9.400 | 35.04 | 15.2 ± |
| Ratio of stem height to total height($H_R$) | 0.894 | 0.550 | 0.756 | 0.07 ± |

Investigation of the form quotient in tree trunk length showed that small diameter trees with diameter classes of 20 to 40 cm minimum trunk diameter (1–1.5 cm) are reduced (fig. 3).

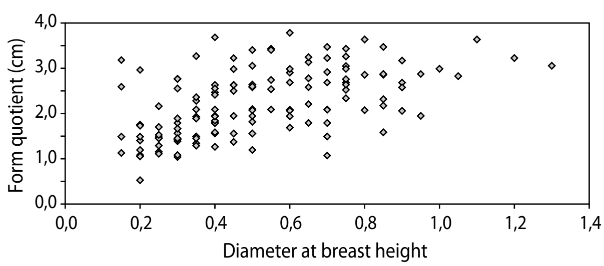


**Figure 3.** Diagram of form quotient

The mean form factor based on diameter is 0.554, and the mean form factor based on volume is 0.576. The scatter diagram of these coefficients reveals that stem form factor in the vegetative stage of small pole is more than that of other trees. Figure 4 and 5, shows the stem form in the vegetative stage of small pole is different than the tree vegetative stages.

The average of stem volume to total volume of trees was estimated to 64.44% (tab. 2).

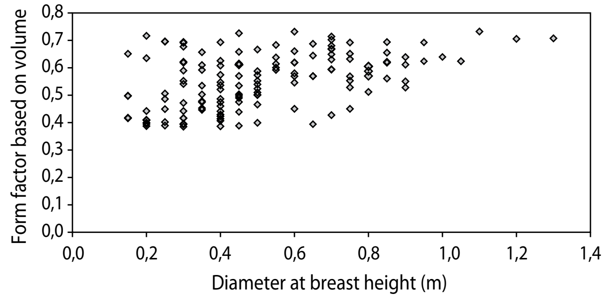


**Figure 4.** The diagram of form factor based on volume

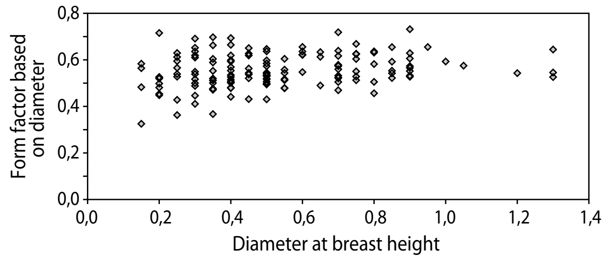


**Figure 5.** The diagram of form factor based on diameter

**Table 2.** Stem volume to total volume ratio using the relative height

| Average of stem volume to total volume ratio (%) | Height above the ground (m) | Method |
|---|---|---|
| 20.2 | 0.1 tree height | Relative height method |
| 34.56 | 0.3 tree height | |
| 47.9 | 0.5 tree height | |
| 52.35 | 0.7 tree height | |
| 58.61 | 0.9 tree height | |
| 64.44 | Total height | |

**Table 3.** Coefficient test results with the factors investigated

| Factors | Regression relation | Coefficient of determination ($R^2$) | Coefficient of correlation (r) |
|---|---|---|---|
| Diameter at breast height with total height | $y = 4.1851x^{-0/3503}$ | 0.43 | 0.66 |
| Diameter at breast height with form quotient | $y = 12.283x^{0/7815}$ | 0.72 | 0.85 |

Regression relation, coefficient of correlation, and coefficient of determination are among the factors investigated and are indicated in table 3.

## Discussion and conclusions

Slenderness factor in forest stands depends on the number of trees in hectares and light competition. It also represents a degree of fertility for the habitat that has a direct relationship with it (Namiranian 2000). Mean slenderness factor(Hd) of the lime tree in the study area was 35.04 percent, that shows the lime tree is stable in this habitat. Small diameter and younger trees (small pole) with 96% slenderness factor are non-stable trees, and larger trees in the saw-timber and maturity stages are the stable trees in the study area with 93.75 slenderness factor. Amini et al. (2007), reviewed beech trees and also concluded that the slenderness factor of beech trees in the small pole stage (diameter classes below 30 cm) is more than 80%, was places them in the unstable group. Akhavan and Namiranian (2007) investigated five important tree species and concluded that the maximum difference in the slenderness factor occurs in the small pole stage and in classes with a diameter of below 30 cm. The form quotient, in addition to showing the reduced diameter of the trunk in different heights, also shows stem form. In this study the mean form quotient of the lime tree was 2.32 cm per meter of stem length. Maximum and minimum form quotients were measured 3.89 and 0.53 cm. So for every one-meter length of tree trunk that is reduced 2.32 cm from the diameter. The lowest decrease in diameter was estimated in small diameter trees (small pole) that show small diameter trees are more cylindrical (Pourbik 1976); Amini et al. (2007) in their study in the Haftkhal forests at Mazandaran province, estimated the mean quotient form of trees to be 1.5 cm. Asli et al. (1976) in the Kheiroudkenar forests with a measurement of 200 trees in classes of 15–120 cm, reported the mean form quotient 1.68 cm. To compare the stem form factor of the lime tree, the form factor based on diameter and volume was used. These coefficients provide a useful analytical tool for the numerical comparison of different groups in tree stems (Mirabdolahi 2009). The means of form factor based on diameter and volume were measured at 0.554 and 0.576. Figure 4 shows that stem form in small diameter trees (small pole) is different from that of the rest of the trees. Next, in the small pole stage, the stem form remains approximately constant. The reason for a difference from the rest of steps in stem form in small pole stage is that the tree is under pressure from adjacent trees and the failure to produce the final form of the tree (Marvimohajer 2005). Kajihara (1984) by examining the stem form of a Japanese tree species showed that tree stems in the young stages do not have certain shapes, but after a stage of development, they are almost constant. In this study, the mean of stem length to tree total height ratio was 0.756. In comparison of both diameter and height of trees, changes of stem length to total length ratio were found to be more influenced by diameter at breast height. In the study area, the investigation of stem volume to tree total volume ratio showed that 64.44% of lime-tree volume is located in the lower half of the stem. Amini et al. (2007), working in the Haftkhal forests at Mazandaran province, showed that 74% of beech tree volume is located in the lower half of the stem.

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